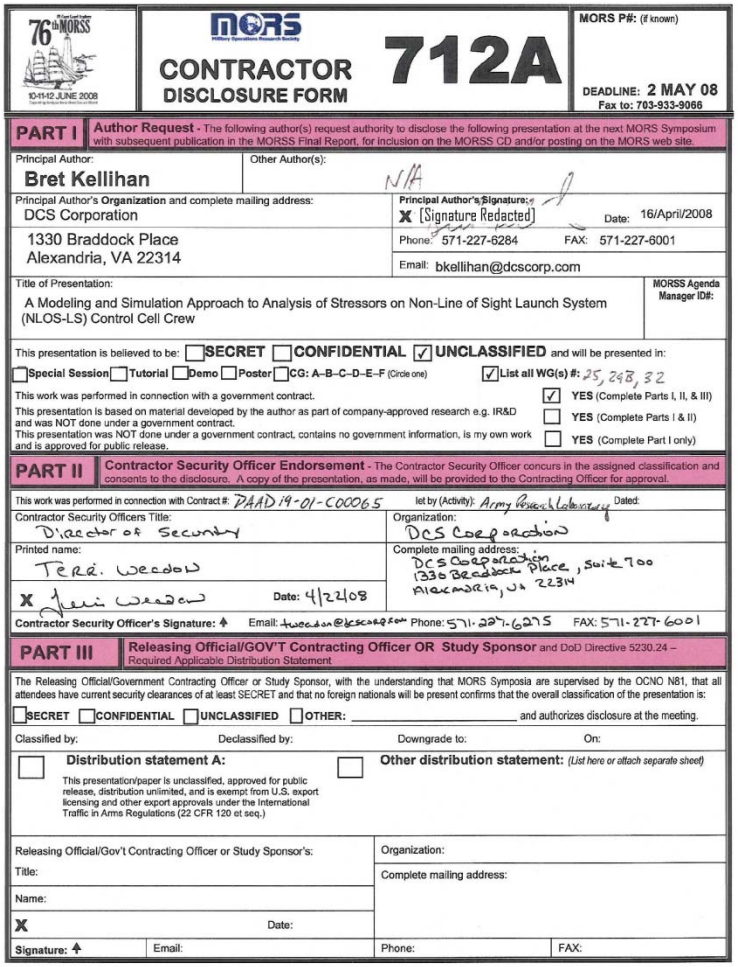

76th MORSS 10-11-12 JUNE 2008

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A Modeling and Simulation Approach to Analysis of Stressors on Non-Line of Sight Launch System (NLOS-LS) Control Cell Crew

Bret Kellihan

DCS Corporation

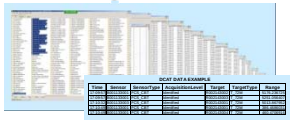
10-12 June 2008

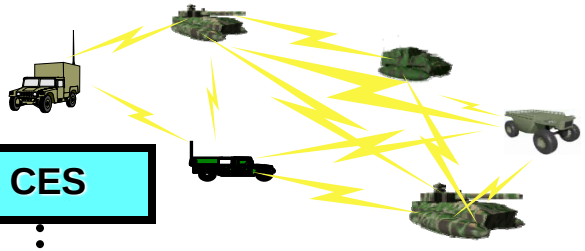
- Part of the RDECOM MATREX Program
- Focused on HPM/HBM of warfighters
- Command Control and Communications Human Performance Model (C3HPM)
  - Based on IMPRINT
  - Ability to alter human performance based on stress conditions
- Historical Models
  - J-CAS
  - TRADOC FireSupport Threads
- FCS SO1 NLOS-LS Modeling and Analysis

- Modeling Architecture for Technology Research and Experimentation
- MATREX provides a unifying M&S architecture, tools, and infrastructure that ease the integration and use of multi-resolution live, virtual, constructive applications

MATREX HLA Environment

Data Analysis & Perspectives





SC4

UAV

DIS LAN 1

DIS LAN 2

CES

Interdapter

Interdapter

DA&P

Data Bases

MTS

SANDS

DOS

OCS

hlaControl

hlaResults

HLA RTI (Data Distribution)

C3HPM

CMS2 Simulation

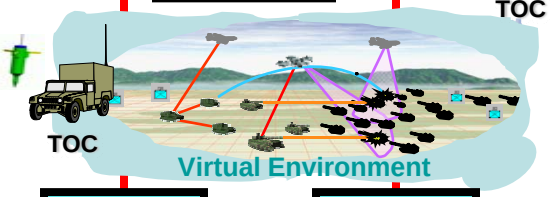
CMS2 Control

OTB/OOS

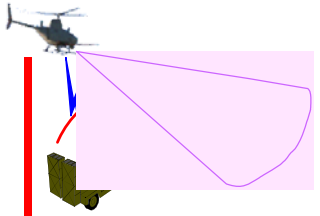
MC2

NEC2

SLAMEM



TOC



HLA Grid

HLA Simulations

HLA Infrastructure

DIS

ARMS

AMS

LVS

VDMS

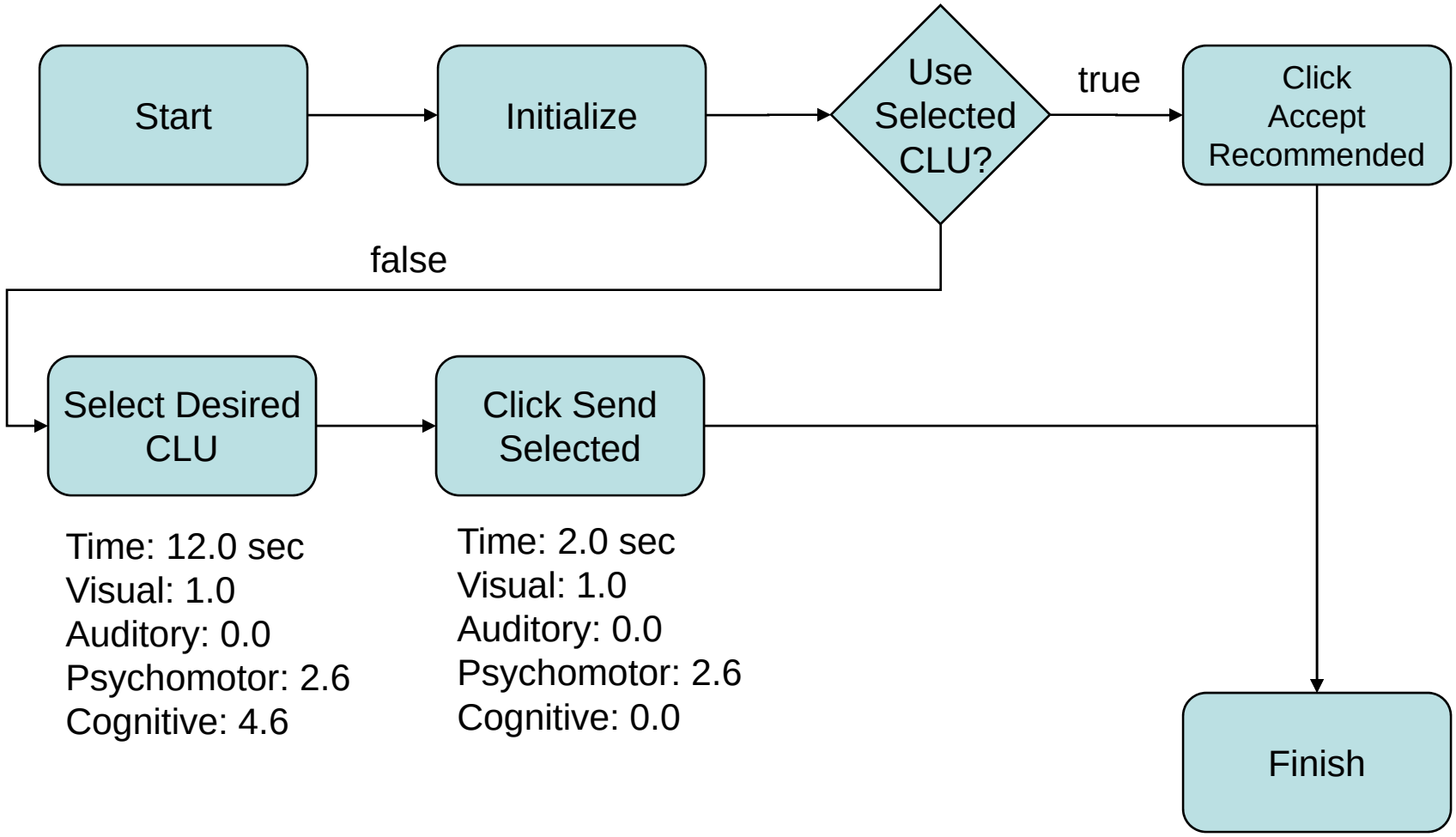
MSLS

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

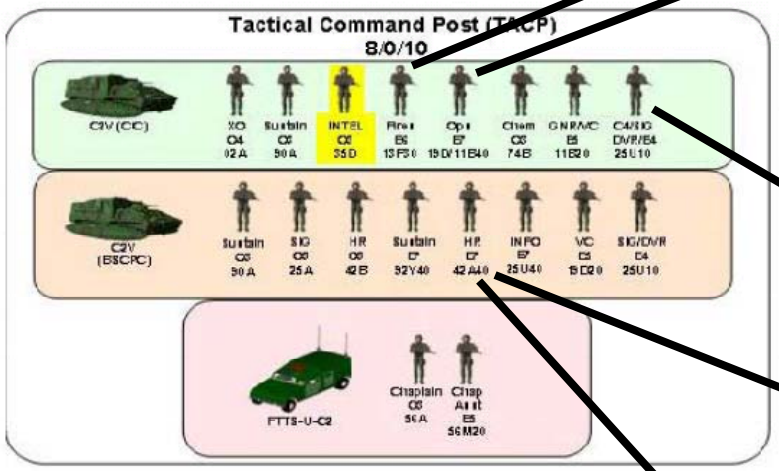
Command Control and Communications Human Performance Model (C3HPM)

- Tool for Human Behavior and Human Performance Modeling
- Based on IMPRINT (ARL tool)
- Task Level Analysis
  - Human Timelines
  - Workload
  - Stressors
- Models stored in an Ontology to provide simulation independent representation of behavior

Sample Task Network (Service)

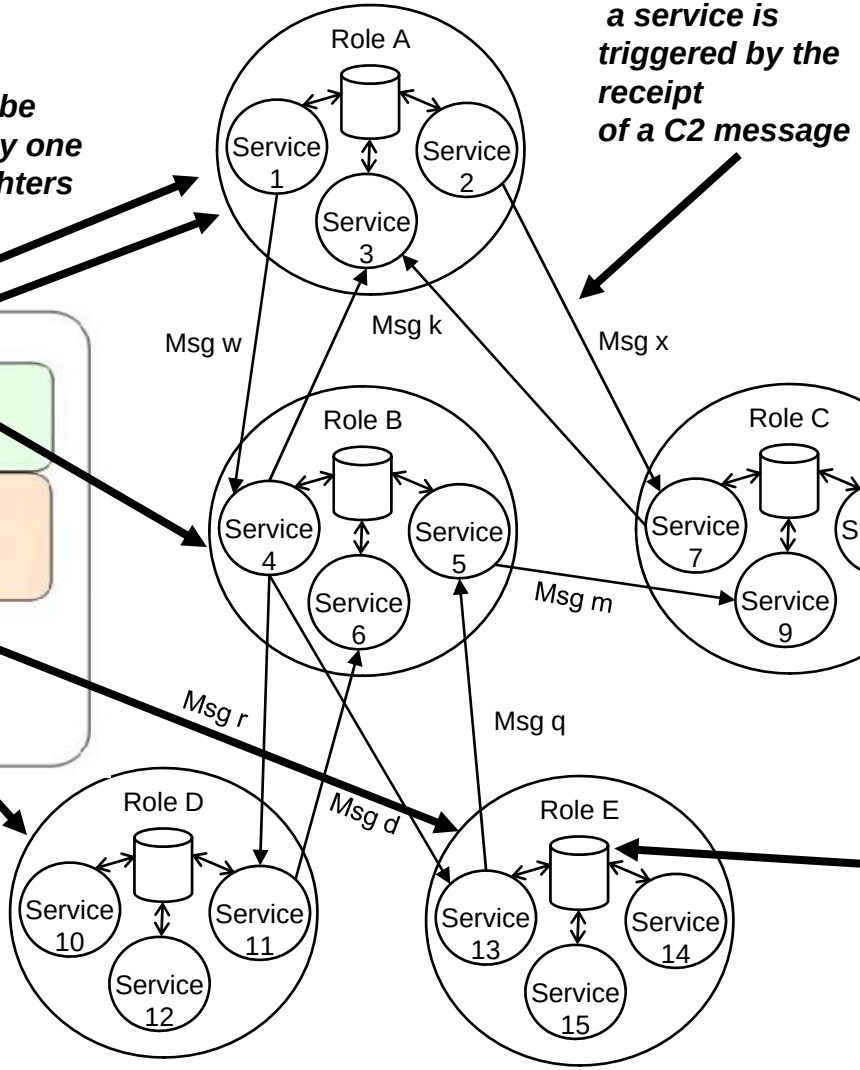


Modeling Warfighter Behavior as Roles and C2 Services

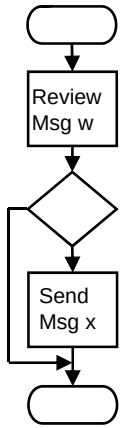


Each role may be implemented by one or more warfighters in the force

Each warfighter may implement one or more roles



Performance of a service is triggered by the receipt of a C2 message



Each service is defined as a task network

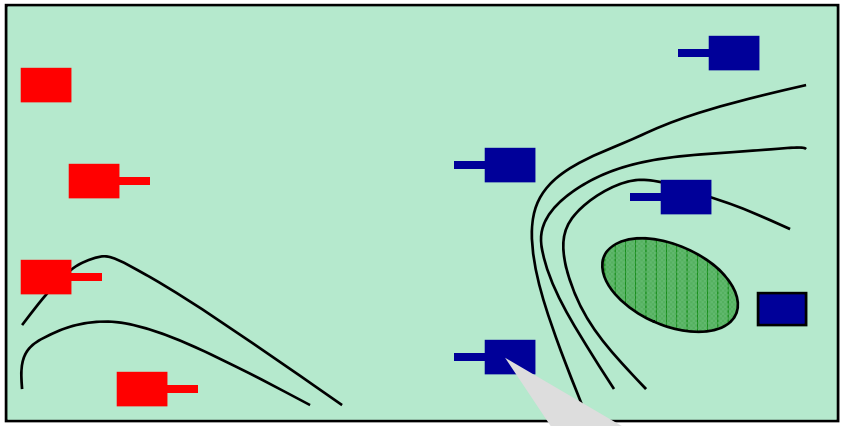
Information may be shared between services within a role

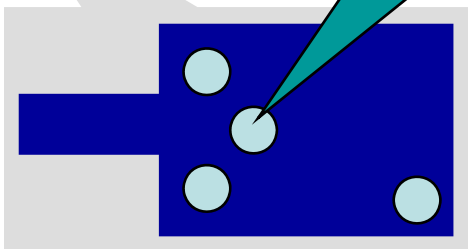
C3 Human Performance Model (C3HPM)

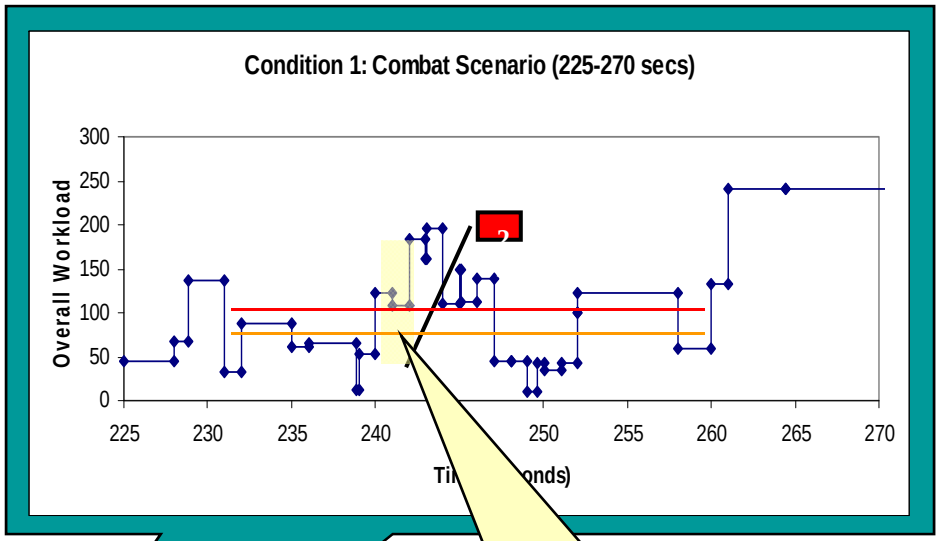
Operator workload is driven by operational scenario, not random numbers

- **COP management**
- **External commo**
- **Scenario events**

System of Systems Simulation







How did human performance impact platform effectiveness based on operator workload?

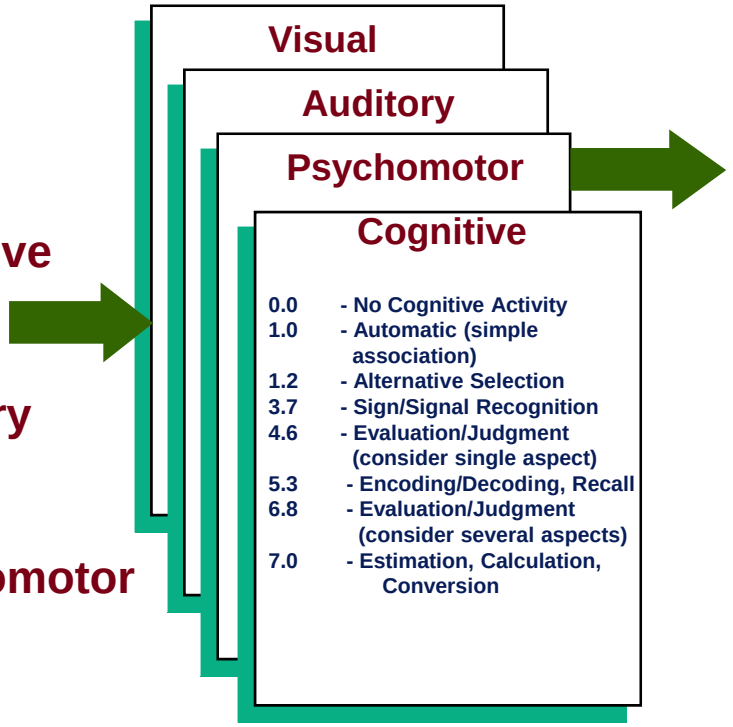
Q: Why didn't the MCS engage the Draega when it should have been in full view and lose initiative in the engagement?

C3HPM Simulation Execution
IMPRINT Task Characterization

Mission Tasks → **Which Brain Resources Involved?** → **Degree of Resource Use?** → **Stressors by Task Type**

1. monitor alarms
2. decide response action
3. pull trigger
.
.
.
n. task n

→ Visual
→ Cognitive
→ Auditory
→ Psychomotor



Task Type	MOPP	Heat	Cold	Noise	Sleepless Hours	On The Move
Fine Motor Discrete	T	A	T			TA
Fine Motor Continuous					TA	TA
Gross Motor Light	T		T			
Gross Motor Heavy						
Commo (Read & Write)		A				TA

Application of C3HPM Human Performance Modeling to FCS SO1 NLOS-LS

Provides a human-fidelity modeling capability that can support force analysis and organizational design

- Explore effective Tactics Techniques and Procedures (TTP's) to deploy, operate and maintain NLOS-LS technology with constructive models in a dynamic environment
  - Analysis of Alternatives from the human performance perspective
  - Alternative task breakdowns, flow, manning, timings and constraints
  - Measure effectiveness in environmental extremes that can not be easily field tested, such as performance degradation due to MOPP gear
- Effects of alternative information flows
  - Where decisions should be made
  - How decisions should be made
  - Levels of Situation Awareness given human constraints (cognitive, physical, visual and auditory)

Supports MANPRINT Analysis

- Man-machine task allocation
- How many soldiers?
- Of what type?
- Trained how?
- Used safely under what conditions?

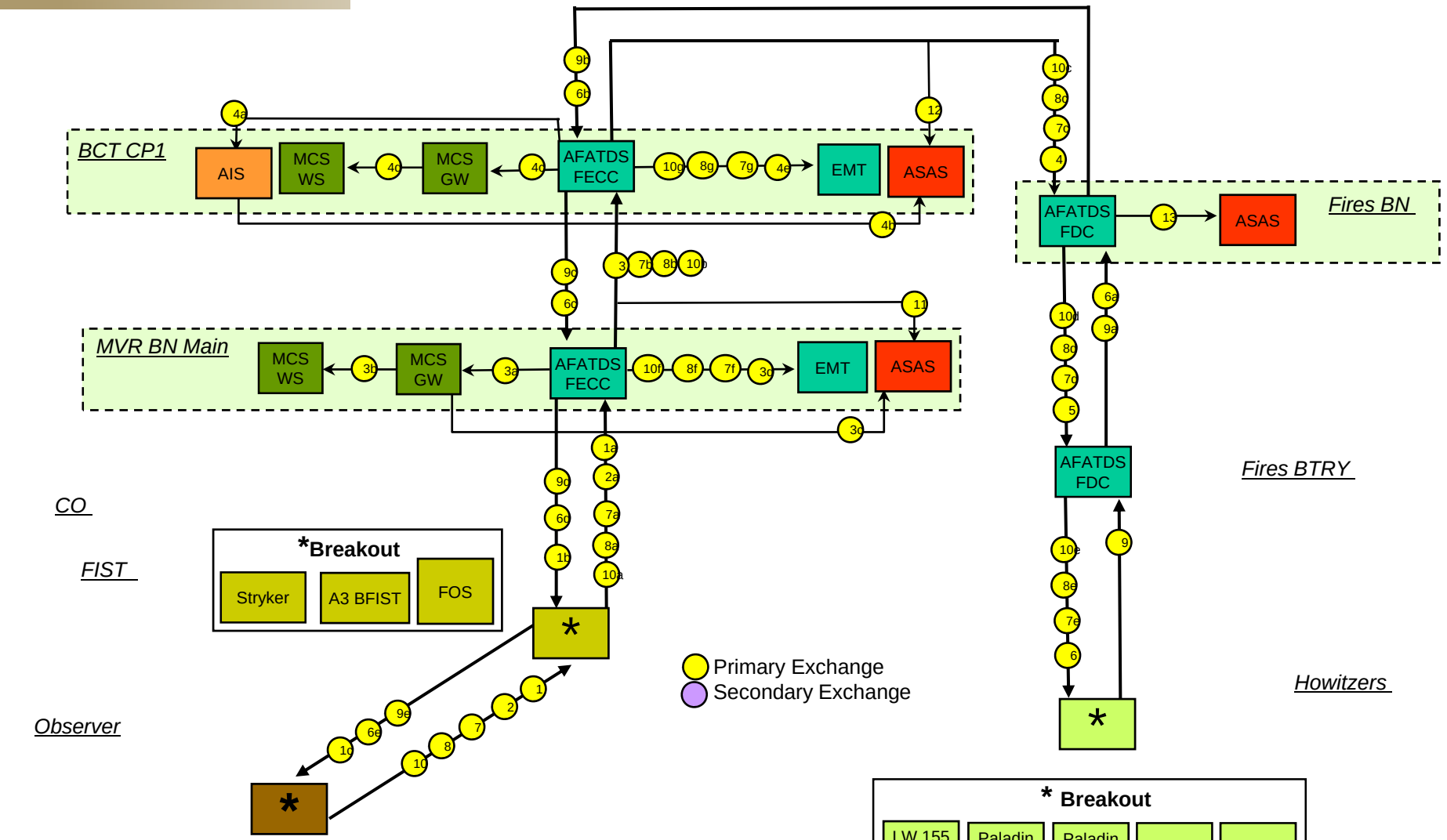
Provides cost-effective capability to exercise live and virtual simulations within MATREX in a constructive manner to support experimentation

- Constructive models of operators of virtual simulations
- Constructive models of operators of live applications

C3HPM Mission Thread Based Modeling Process

- ABCS Software Block Intra Army Interoperability Certification Mission Thread Products
  - Used by CTSF to test interoperability of current force battle command systems
  - Provides description of command and control behaviors
  - Can be readily transformed into behavior models with some SME input

Mission Thread Example



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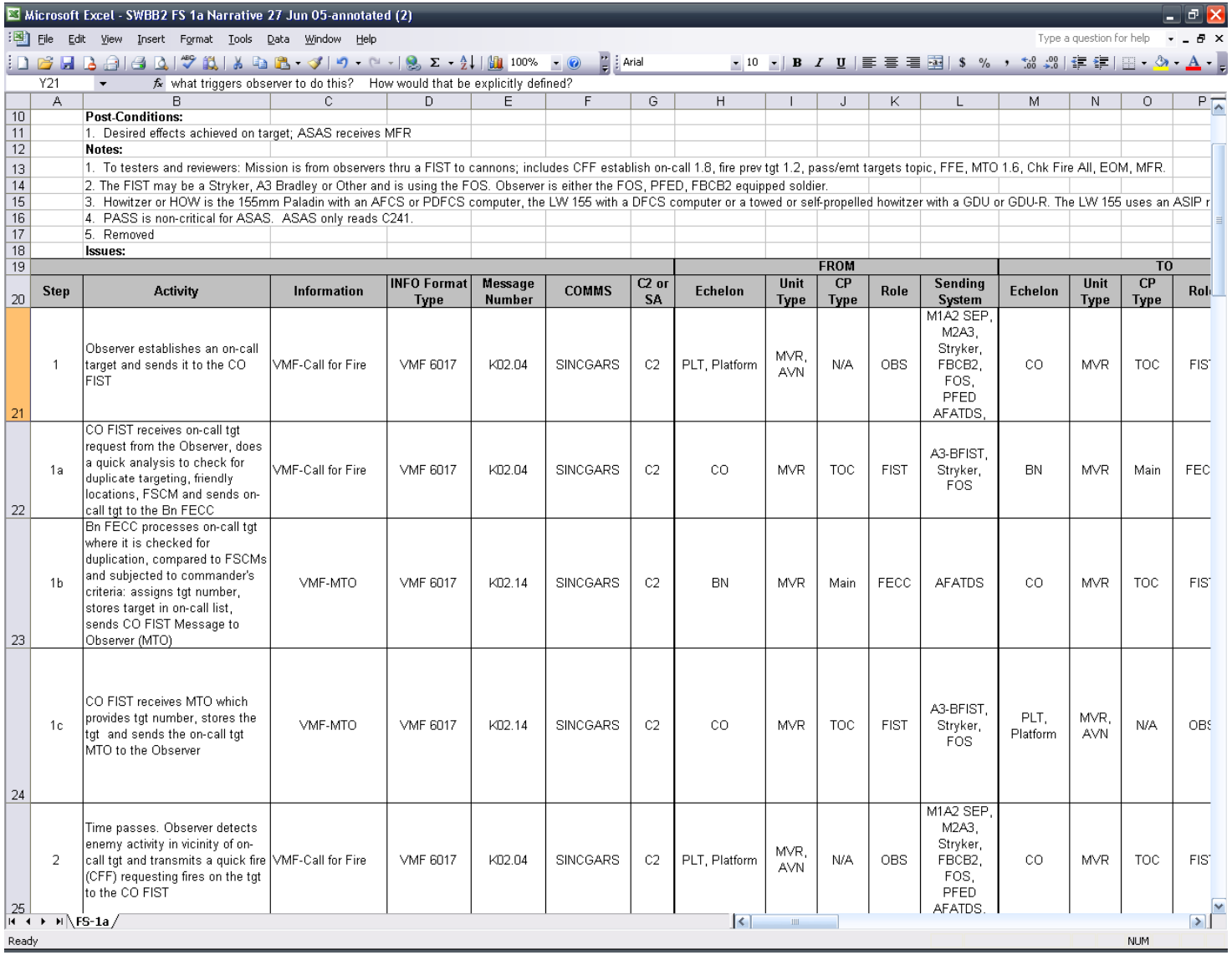
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Mission Thread Example



Microsoft Excel - SWBB2 FS 1a Narrative 27 Jun 05-annotated (2)

File Edit View Insert Format Tools Data Window Help

Y21 what triggers observer to do this? How would that be explicitly defined?

Post-Conditions:

1. Desired effects achieved on target; ASAS receives MFR

Notes:

1. To testers and reviewers: Mission is from observers thru a FIST to cannons; includes CFF establish on-call 1.8, fire prev tgt 1.2, pass/emt targets topic, FFE, MTO 1.6, Chk Fire All, EOM, MFR.
2. The FIST may be a Stryker, A3 Bradley or Other and is using the FOS. Observer is either the FOS, PFED, FBCB2 equipped soldier.
3. Howitzer or HOW is the 155mm Paladin with an AFCS or PDFCS computer, the LW 155 with a DFCS computer or a towed or self-propelled howitzer with a GDU or GDU-R. The LW 155 uses an ASIP r
4. PASS is non-critical for ASAS. ASAS only reads C241.
5. Removed

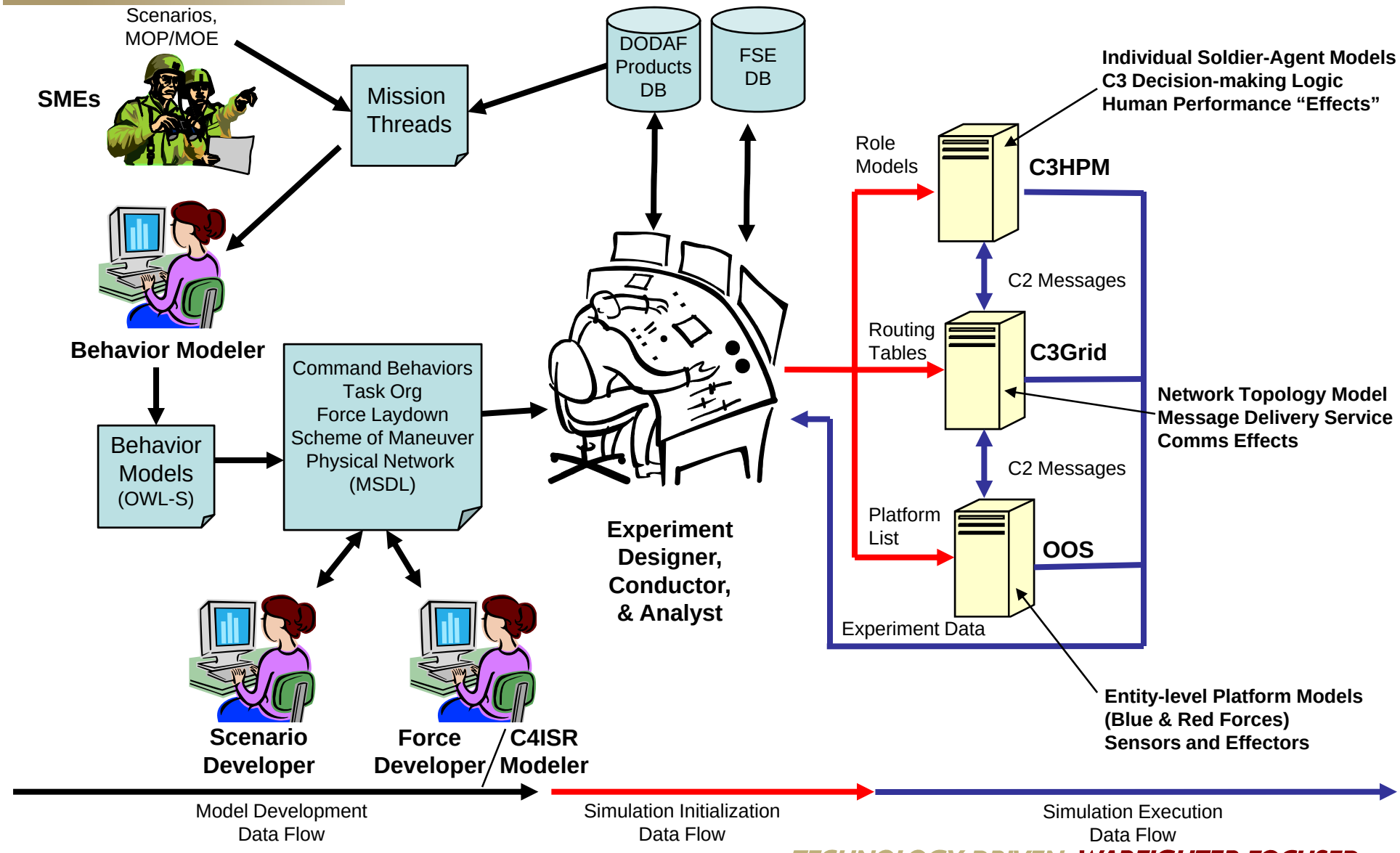
Issues:

								FROM					TO			
Step	Activity	Information	INFO Format Type	Message Number	COMMS	C2 or SA	Echelon	Unit Type	CP Type	Role	Sending System	Echelon	Unit Type	CP Type	Rol
1	Observer establishes an on-call target and sends it to the CO FIST	VMF-Call for Fire	VMF 6017	K02.04	SINCGARS	C2	PLT, Platform	MVR, AVN	N/A	OBS	M1A2 SEP, M2A3, Stryker, FBCB2, FOS, PFED AFATDS,	CO	MVR	TOC	FIS
1a	CO FIST receives on-call tgt request from the Observer, does a quick analysis to check for duplicate targeting, friendly locations, FSCM and sends on-call tgt to the Bn FECC	VMF-Call for Fire	VMF 6017	K02.04	SINCGARS	C2	CO	MVR	TOC	FIST	A3-BFIST, Stryker, FOS	BN	MVR	Main	FEC
1b	Bn FECC processes on-call tgt where it is checked for duplication, compared to FSCMs and subjected to commander's criteria: assigns tgt number, stores target in on-call list, sends CO FIST Message to Observer (MTO)	VMF-MTO	VMF 6017	K02.14	SINCGARS	C2	BN	MVR	Main	FECC	AFATDS	CO	MVR	TOC	FIS
1c	CO FIST receives MTO which provides tgt number, stores the tgt and sends the on-call tgt MTO to the Observer	VMF-MTO	VMF 6017	K02.14	SINCGARS	C2	CO	MVR	TOC	FIST	A3-BFIST, Stryker, FOS	PLT, Platform	MVR, AVN	N/A	OBS
2	Time passes. Observer detects enemy activity in vicinity of on-call tgt and transmits a quick fire (CFF) requesting fires on the tgt to the CO FIST	VMF-Call for Fire	VMF 6017	K02.04	SINCGARS	C2	PLT, Platform	MVR, AVN	N/A	OBS	M1A2 SEP, M2A3, Stryker, FBCB2, FOS, PFED AFATDS,	CO	MVR	TOC	FIS

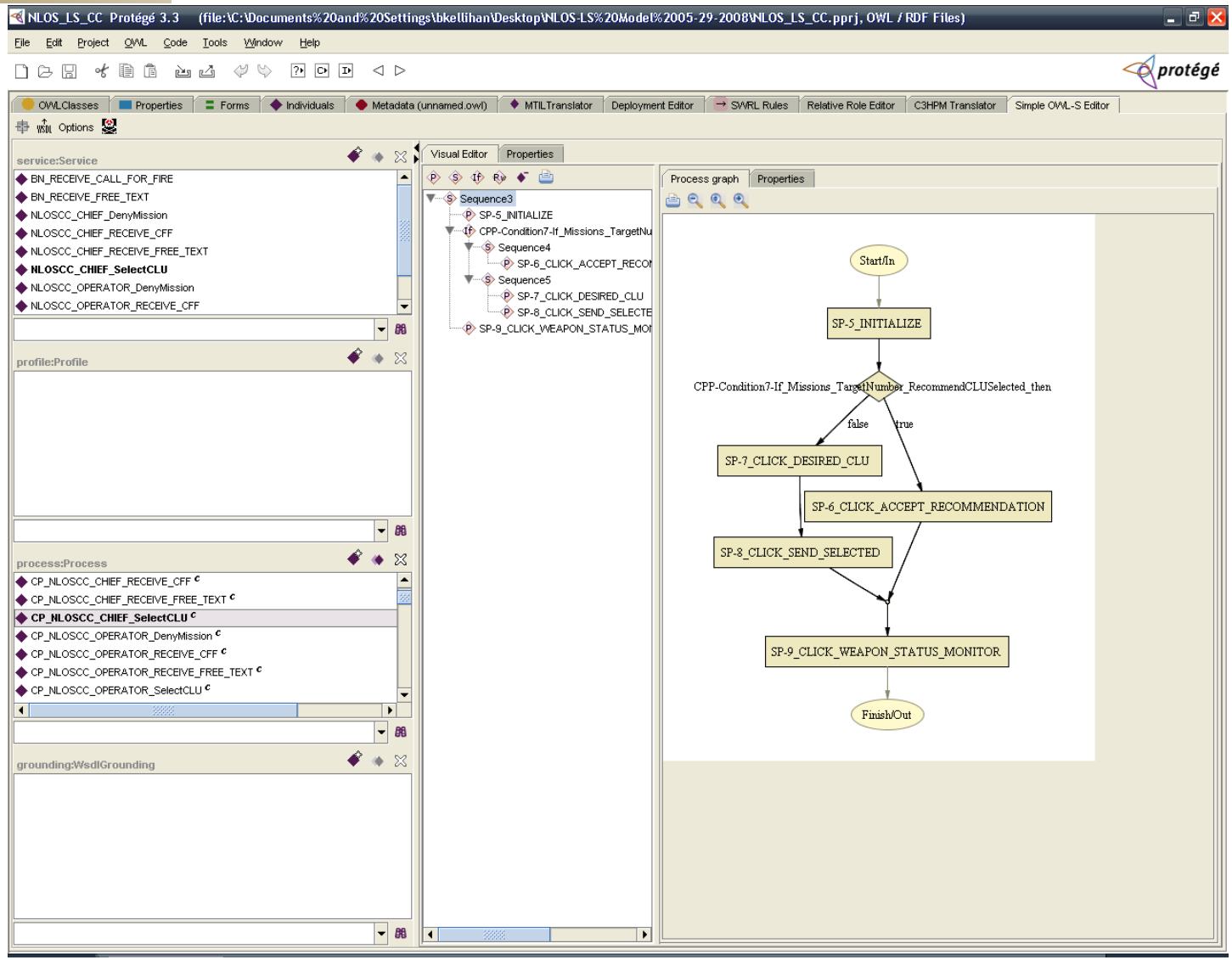
FS-1a

Ready NUM

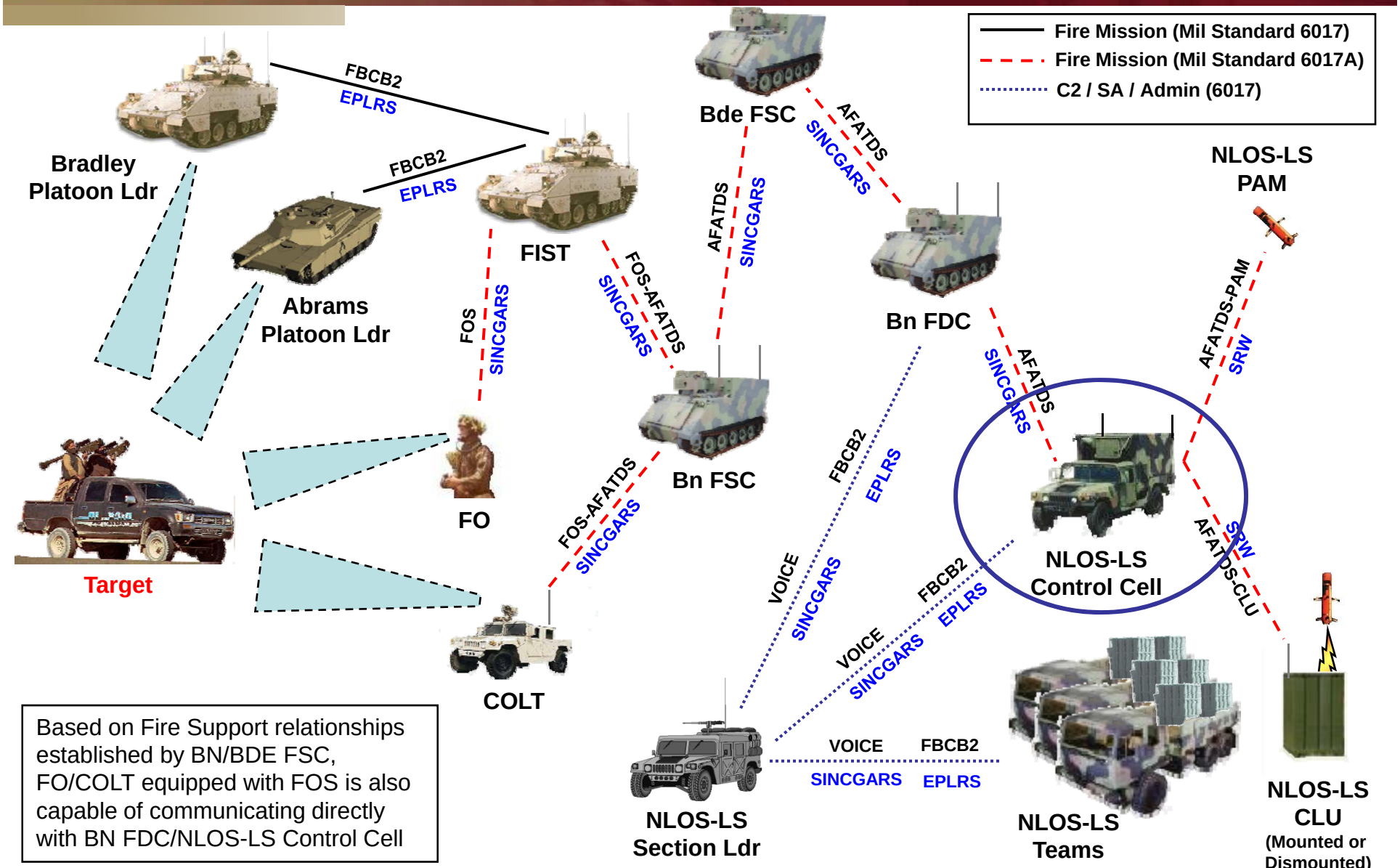
C3HPM Modeling



Behavior Model Representation in OWL-S



NLOS-LS Proposed Current Force C2 Integration

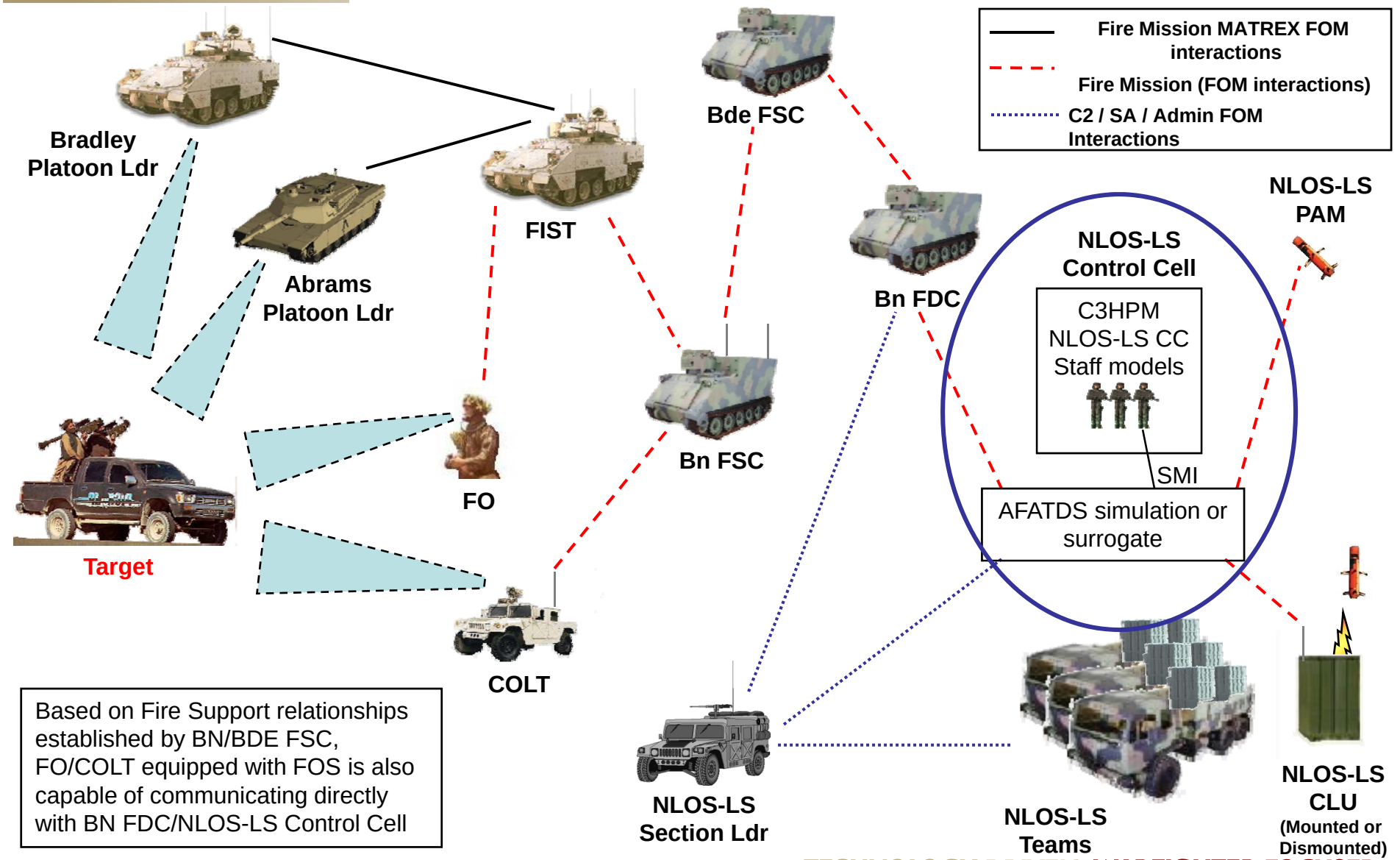


Based on Fire Support relationships established by BN/BDE FSC, FO/COLT equipped with FOS is also capable of communicating directly with BN FDC/NLOS-LS Control Cell

Understanding of the Problem
NLOS-LS Task Organization

- The FCS Spin Out 1 NLOS Launcher System (LS) Section will consist of a two man section HQ, a three man NLOS-LS Control Cell (CC), and three two man teams that operate the six Container/Launch Unists (CLU).
- The AFATDS operator in the CC will perform all the tactical and technical fire control for NLOS-LS for the entire BCT AO
  - Reliance on automation in AFATDS to handle much of the control, and coordination
  - Reliance on higher echelon (Bde FSC, Fires Bn FDC) to perform coordination, and deconfliction of missions before being sent to the NLOS-LS CC
- Experimental excursions to study the limits of one CC was performed
  - Physics based limits of equipment can be calculated
  - Limits of human operator(s) are uncertain
- Experimental excursions to study the effect of two CCs in the NLOS-LS section is also desired
  - Possible benefit of extending the communication range
  - Possible benefit of supporting independent movement and operations
  - Eliminating the single point of failure

FCS Spin Out 1 NLOS-LS Control Cell Modeling

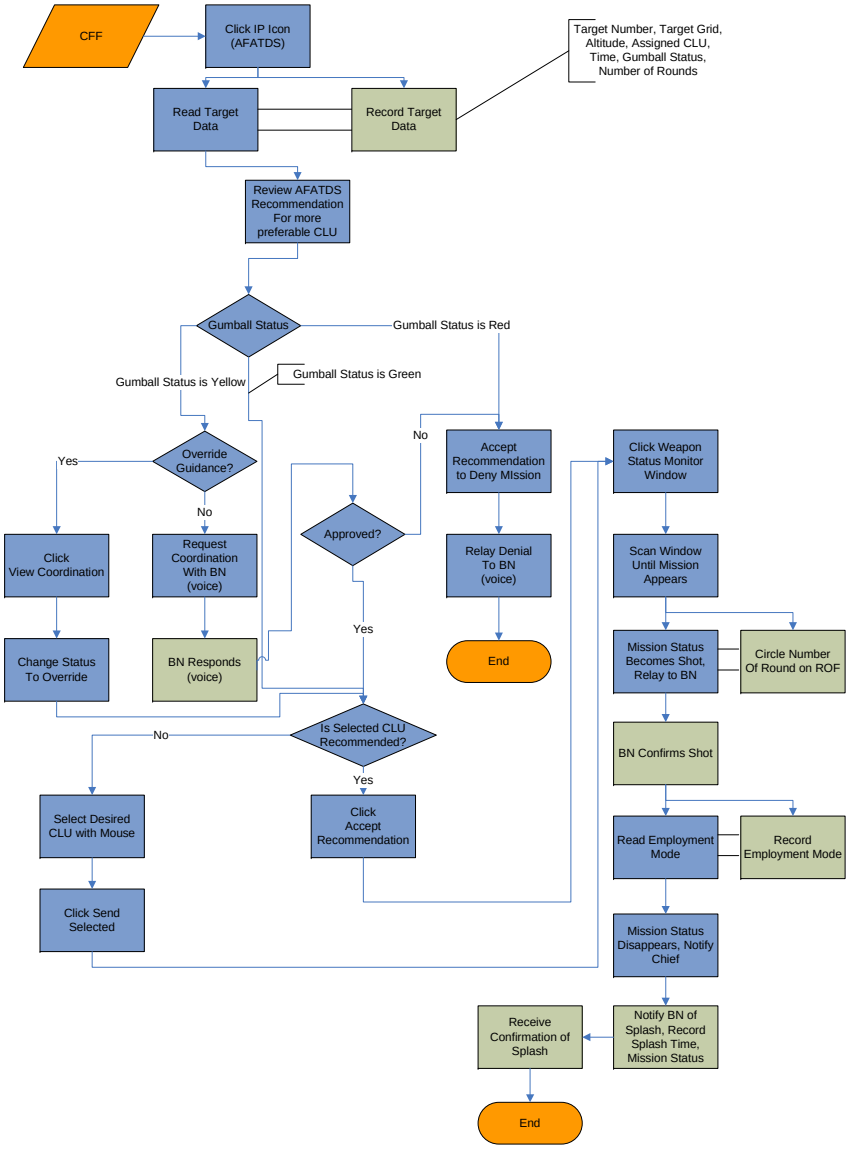


Based on Fire Support relationships established by BN/BDE FSC, FO/COLT equipped with FOS is also capable of communicating directly with BN FDC/NLOS-LS Control Cell

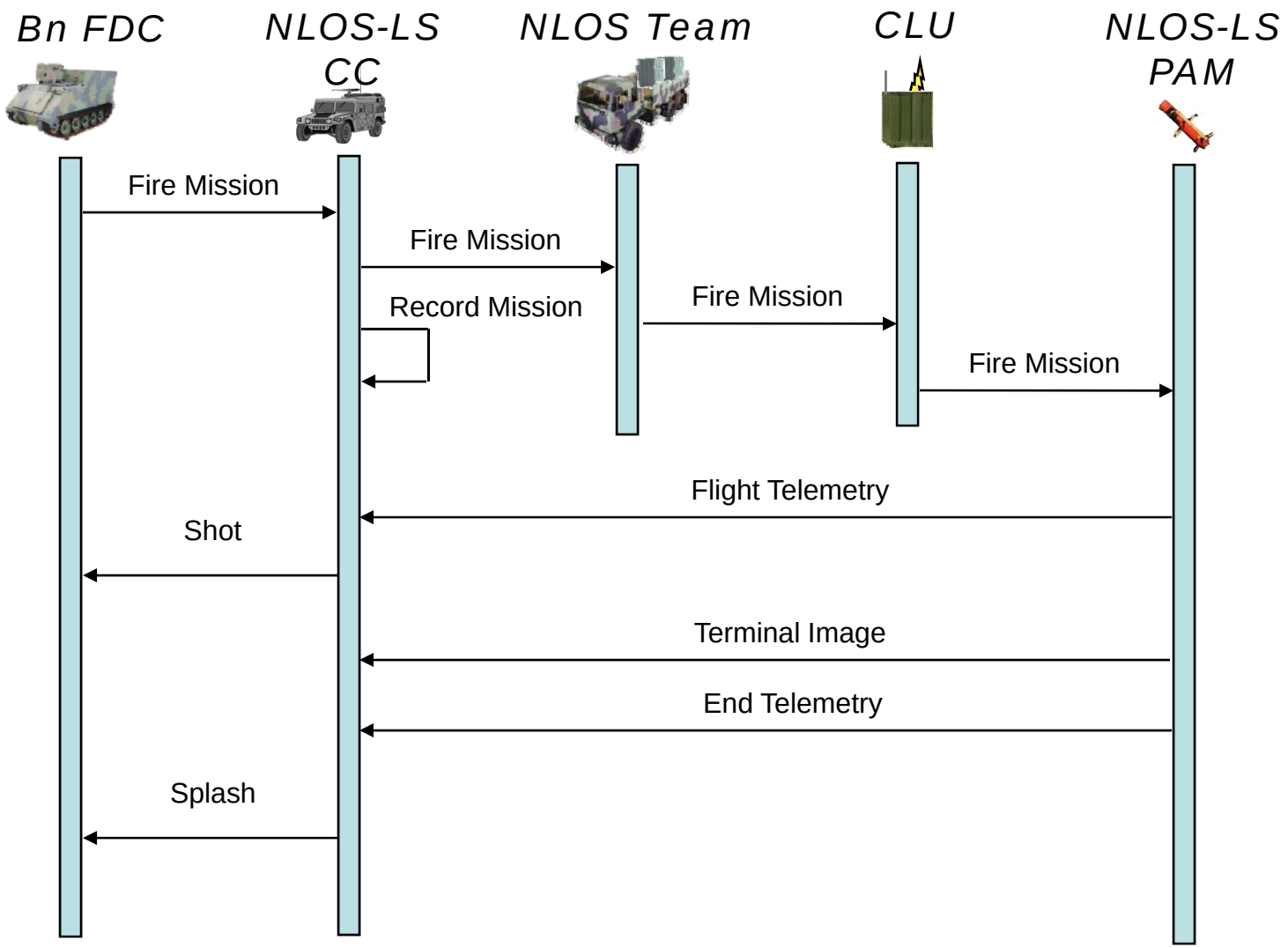
FCS Spin Out 1 NLOS-LS Model Development

- Observers collected data at the Fires Battle Lab at Ft. Sill during the pilot test (July 2007)
- Modeling is focused on the Control Cell Chief and AFATDS Operator
- Developed Stub models to stimulate and respond to the operators modeled in the C3HPM
  - Precision Attack Munition
  - AFATDS
  - Fire Mission Generator

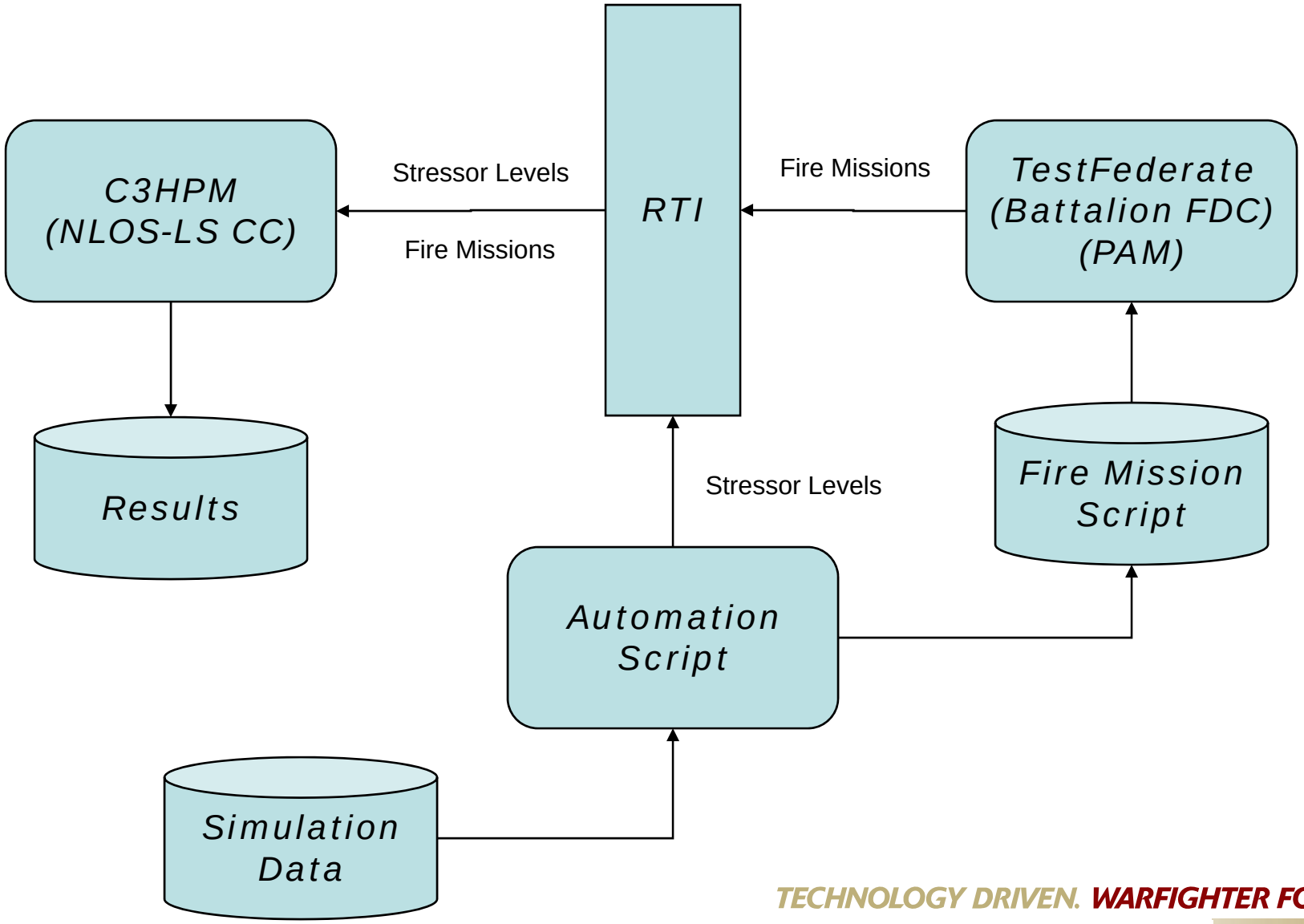
NLOS-LS CC C3HPM Model



Fire Mission Green Sequence



NLOS-LS CC Test Setup



Statistical Analysis

Qualitative Analyses

- Observation of B-L times varying across nearly 2 orders of magnitude (range ~ 150 – 20,000+ sec) indicated a need for transformation prior to hypothesis testing
  - ANOVA models assessed logarithmically transformed B-L times (units of *ln[sec]*)
  - Later hypothesis tests validated this transformation by:
    - revealing significant effects that were masked by variance heterogeneity
    - attenuating magnitude of effects that were exaggerated by difference due to scale

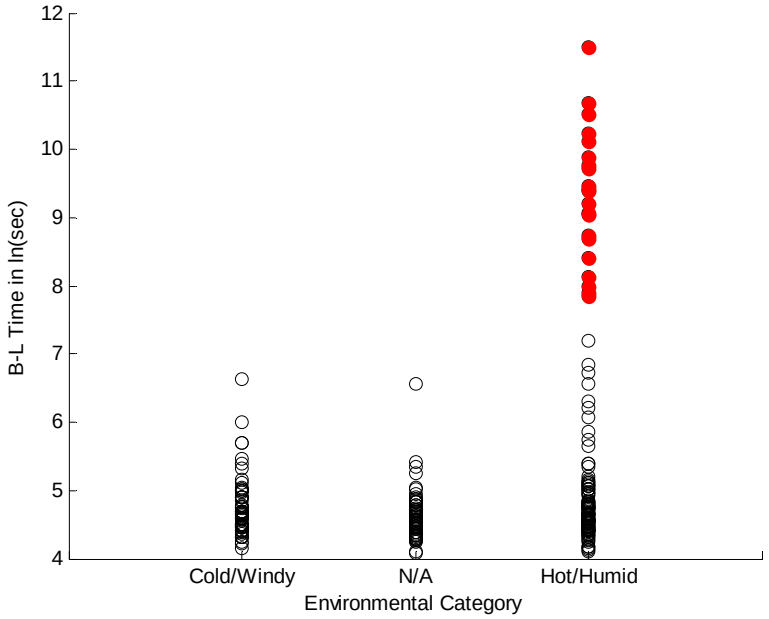
- Graphical assessment of relationship between workload and B-L times indicated potential value in treating this variable as continuous rather than categorical
  - later hypothesis tests validated pooling degrees of freedom in this manner as valuable for estimation of the relationship between workload and performance
  - similar assessments on other independent variables did not lead to similar conclusions (i.e. treating MOPP levels as continuous reduced ability to detect differences in performance)

Statistical Analysis

Formal Hypothesis Tests

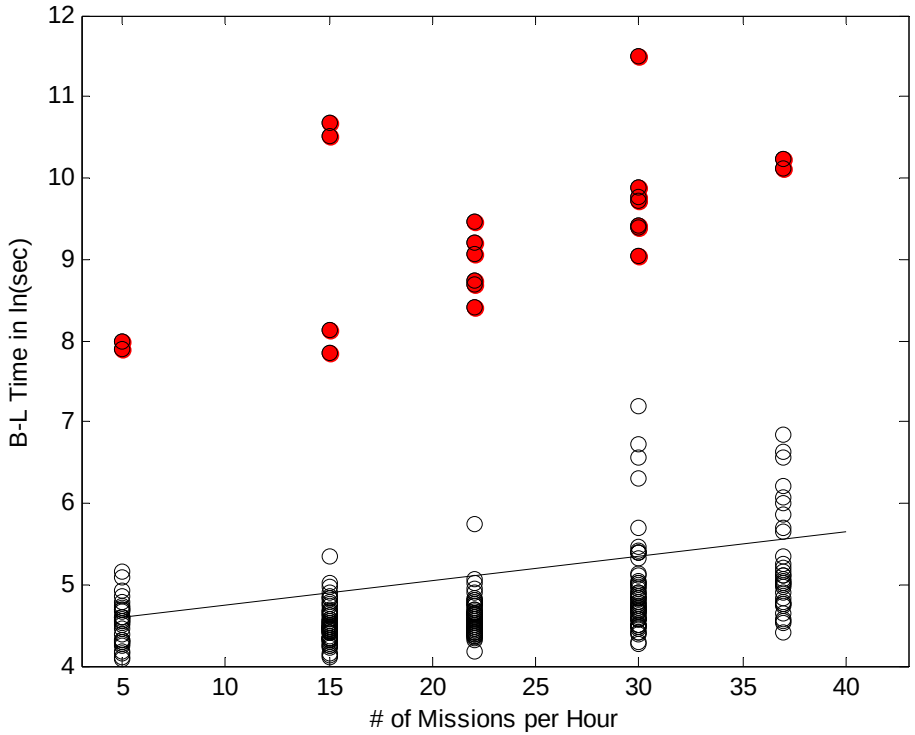
- n-way ANOVAs were conducted using MATLAB 7.0
- backward selection was used to determine main and interaction effects to be included in the final model
  - All main effects and interactions up to the third order were initially examined
  - Non-significant terms were removed and the model was re-run
  - When interactions were observed, associated main effects remained in the model regardless of level of univariate significance (i.e. MOPP and Movement exposure were included despite lacking significance as main effects)
- The final statistical model:
  - Independent variables:
    - Continuous variable
      - » Workload (# missions/hour)
    - Categorical variables
      - » MOPP (protective gear) level (0,3,4)
      - » Noise (50-60, 70-80 decibels)
      - » Movement exposure (none, 1-2, 2-3, 3-4, 4-5 Hours)
      - » Environmental category (Cold/windy, nominal, Hot/humid)
    - Interaction terms
      - » Workload × MOPP
      - » Noise × Movement Exposure as interactions
  - Dependent variable: Log-transformed B-L time

Initial Results of NLOS-LS CC Modeling and Analysis



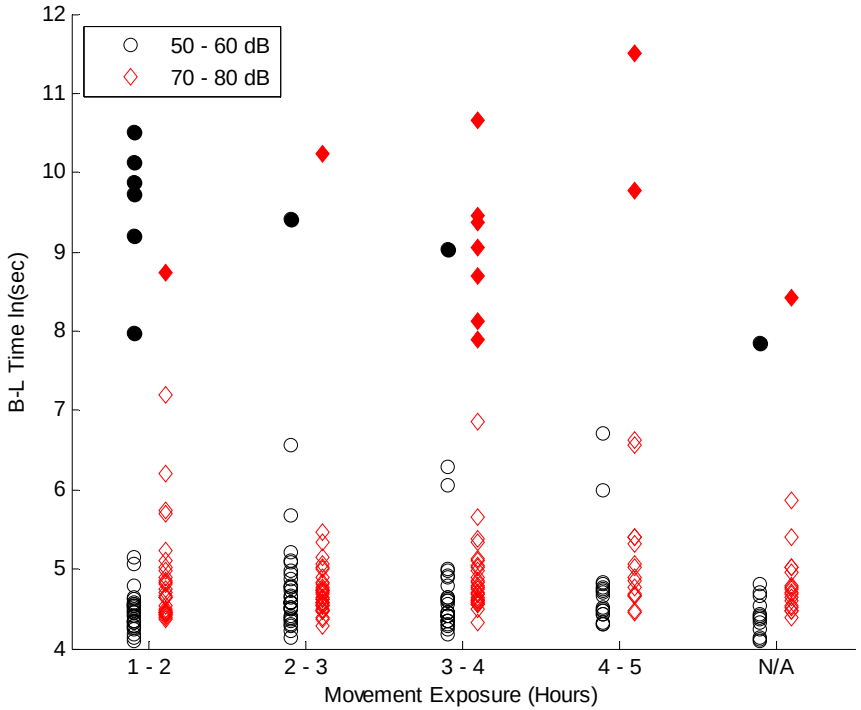
- Significant main effect for environmental category ($F_{2,242} = 16.57$, $p < 0.001$);
  - Performance was more variables in hot/humid conditions than either of the other two categories
- Qualitative inspection of results indicated a potential heat-humidity interaction, however, because of how the simulation conditions were run, it was not possible to formally test this interaction within the same statistical model as other variables
  - As ambient temperature increased beyond 40° C, performance appeared to diminish at lower levels of relative humidity (illustrated by solid red data points)
    - When ambient temperature was set to 40-44°C, worst performance was observed when RH was in the range of 61-70%;
    - When ambient temperature was 45° C or greater, considerable performance effects were seen at any RH above 51%

Initial Results of NLOS-LS CC Modeling and Analysis



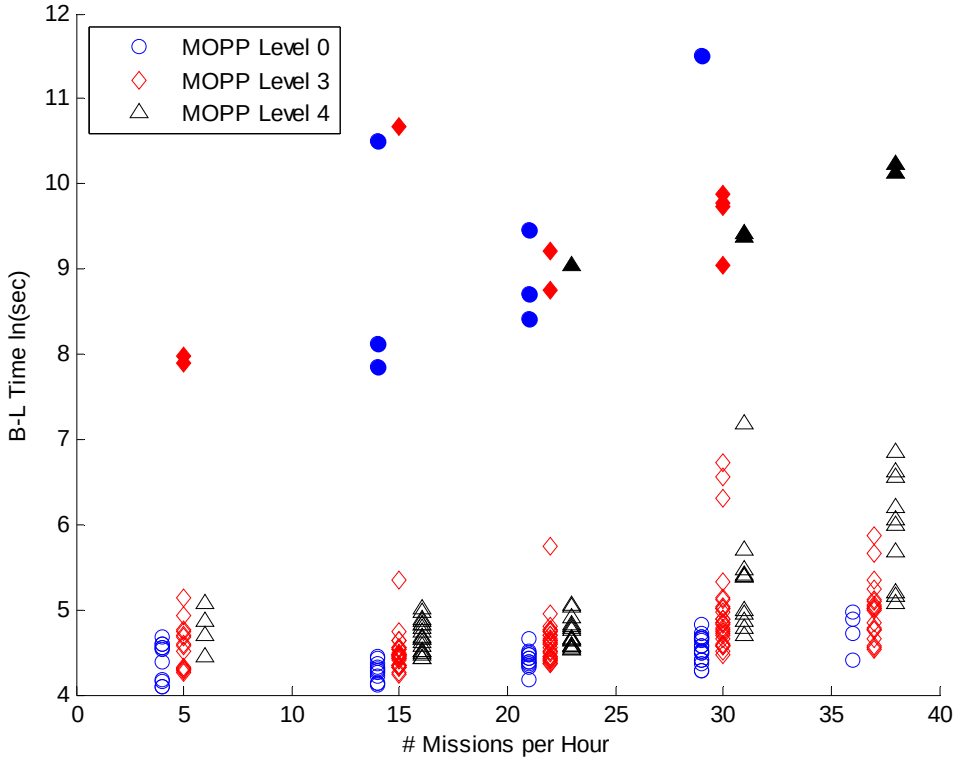
- Significant main effect for workload ($F_{1,242}$ = 15.28, $p < 0.001$), which was represented as a regression effect (continuous variable)
- Solid red circles indicate conditions with a high heat index
  - Despite the qualitatively different values for the high heat index conditions, the same linear trend was observed for all data as a function of workload

Initial Results of NLOS-LS CC Modeling and Analysis



- Significant main effect for noise ($F_{1, 242} = 6.2$, $p < 0.02$)
  - It seemed that performance was slightly degraded as ambient noise was at a level that would be perceived as at least twice as loud as normal conversation
- Significant interaction between noise and movement exposure ($F_{4,242} = 2.76$, $p < 0.03$)
  - It appears as if there may be no effect of movement exposure at normal conversational noise levels (excluding the nonlinear influence of high heat index conditions)
  - However, when noise is at a level that would be perceived as double the volume, there seems to be a slight linear reduction in performance with increased duration of movement exposure

Initial Results of NLOS-LS CC Modeling and Analysis



Significant interaction between MOPP and Workload ($F_{2, 242} = 3.89$, $p < 0.03$)

- The relative increase in B-L times as a function of workload appeared greater in conditions simulating MOPP level 4 and, in particular, as workload increased to 20 missions per hour and beyond
- When simulating MOPP level 3, there seemed to be a similar increase in B-L times as workload increased beyond 30 missions per hour
- When MOPP level was 0, there did not appear to be a consistent influence of workload

Results Summary

- The two most dramatic effects on B-L time were environmental category and number of missions per hour.
- The effect of environmental category appeared almost entirely due to a particular combination of heat/humidity conditions involving the greatest heat index; for temperatures in the range of 40-44 °C, performance declines were observed at relative humidity above 61% and for temperatures 45°C and above, performance declines appeared around 51% relative humidity.
- Evidence indicates that MOPP level may also be a minor contributor to the influence of workload – in particular, it seems that 20+ missions per hour while wearing MOPP levels 3 or 4 will be associated with increased variability in performance.
- Finally, there seemed also to be a small effect of ambient noise, where noise levels that are perceived as at least double normal conversational levels will be associated with a small but consistent increase in B-L time and this effect may vary somewhat with duration of exposure to movement.

Potential Future Work

- NLOS-LS SO1
  - Model Test Model Paradigm
  - Awaiting Data collected from SO1 FDT/E
  - Long duration (multi-day) simulations
  - 2 vs. 1 control cell comparison
- JIEDDO
  - Simulation of TTPs of warfighters using defeat devices
  - Simulation of insurgents using IEDs
- JPEO CBD
  - Develop models of warfighters using proposed Chem/Bio defeat devices to assess effectiveness

Questions?